Spatial pattern analysis of tropical agroforests: methods for ecological and agronomic issues

Ngo Bieng M.A.[1], Babin R.[2,3], Ten Hoopen G.M.[2,3], Yede[3] and Cilas C.[2]

[1]UMR SYSTEM: Fonctionnement et conduite des systèmes de culture tropicaux et méditerranéens. SupAgro, 2 Place Viala, 34060 Montpellier, cedex 1.
[2]UPR Maîtrise des bioagresseurs des cultures pérennes. Avenue Agropolis, 34398 Montpellier, cedex 5.
[3]IRAD: Institut de Recherche en Agronomie pour le Developpement. BP 2067, Yaoundé, Cameroon

Corresponding author: marie-ange.ngo_bieng@cirad.fr

Cocoa based tropical agroforest in south Cameroon

Context

- Tropical agroforests are important cropping regimes for sustainable agricultural production and ecological intensification.
- However, these systems are complex:
  - they are characterized by a high environmental heterogeneity;
  - little is known about their structural organisation and ecological functioning.

The stand above is located near Yaoundé, Cameroon. A large variety of Cocoa trinitario type hybrids has been installed below a semi-deciduous rainforest in 1984, at about 975 trees.ha^{-1}. The companion trees, with a density of 162 trees.ha^{-1} are forest trees (55 %), fruit trees (35 %), and palm trees (9 %).

Objective

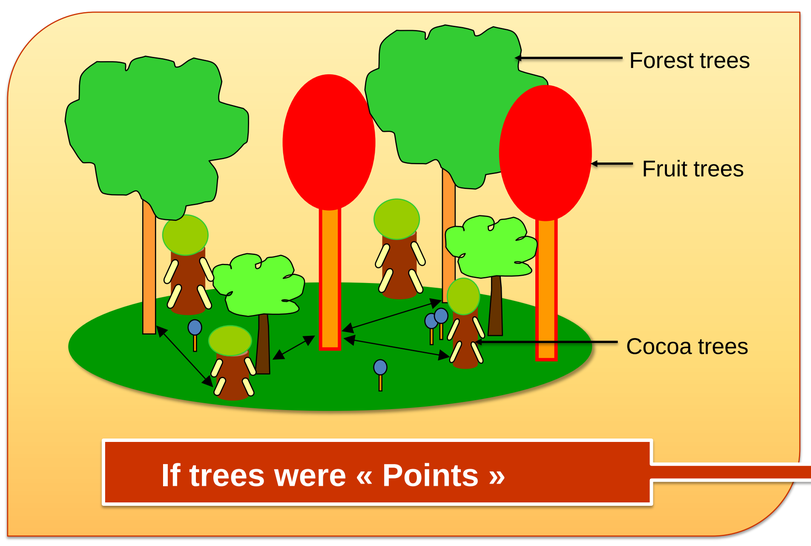
Apply Spatial pattern analyses to improve our knowledge of tropical complex agroforests:

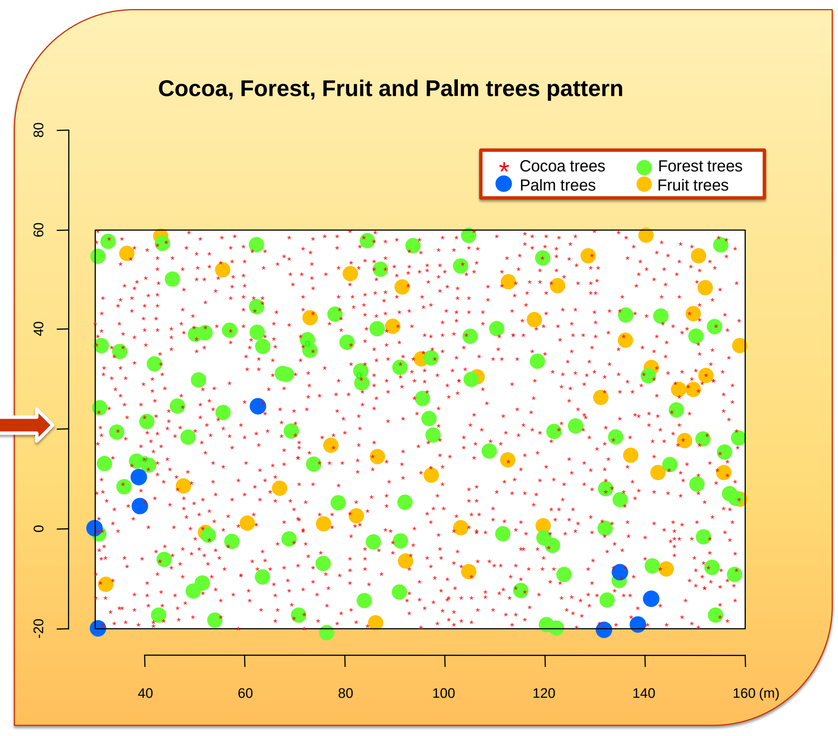
- identify the structural characteristics trough precise characterisation of their spatial organisation;
- provide new insights for understanding the processes underlying agroforestry dynamics and management.

Methods

Spatial pattern analyses aim at characterizing the spatial organisation of individuals. Here we want to assess the horizontal interactions between trees.

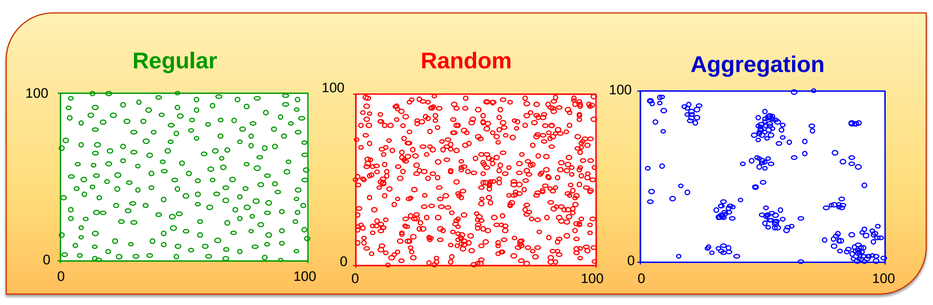
All the individuals of the agroforest stand presented above are localised on a map which presents the position « point » of each individual. Thus, we have the spatial « point » pattern of the individuals in the stand.





Spatial structure analysis

We used a classic method of spatial statistics: K(r) function (Ripley, 1977). This function quantifies the degree of clumping and/or overdispersion of the pattern. For each specific, cocoa or forest trees: we can identify an aggregated, random or regular pattern.



Statistics

The unbiased estimate of K(r) is defined as: $\hat{K}(r) = \frac{1}{\hat{\lambda} N} \sum_{i=1}^{N} \frac{\pi r^2}{A_{ir}} \sum_{j=1, i \neq j}^{N} c(i,j,r)$

N: the number of trees of the corresponding group in the plot

A: area of the plot

c(*i*,*j*,*r*), for a tree *i* and its neighbour *j* of the same group, is an indicator equal to 1 if *j* is within the circle of radius *r* around *i*, or otherwise 0.

• *Air:* the area of the circle included within A

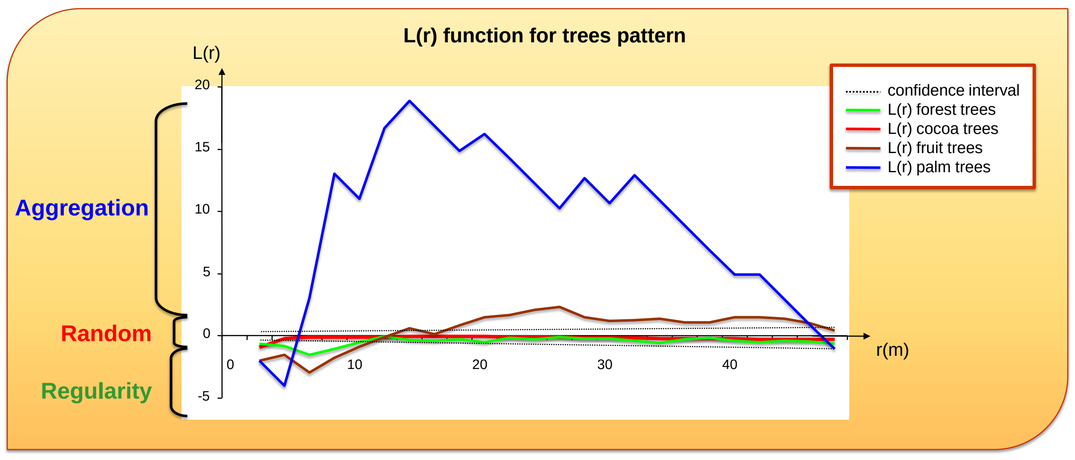
For graphical interpretation we used *L*(*r*) a square-root transformation of *K*(*r*):

$$\hat{L}(r) = \sqrt{\frac{\hat{K}(r)}{\pi}} - r$$

The value of is 0 for a random spatial distribution at distance *r*; values > 1 indicate clumping, and values <1 indicate regular distributions.

Results

- Cocoa trees (red curve) are regularly spaced at small scale (2m apart), and are randomly distributed above: their pattern is reflecting the plantation distance.
- Forest trees (green curve) are also regularly spaced (about 5m apart). This pattern is also reflecting farmer interventions (thinning), and no natural regeneration.
- Fruit trees (brown curve) are distributed in clusters (radius of 25m). Inside these clusters, individuals are regularly spaced (about 5m apart). This may reflect a regular plantation, followed by a natural regeneration and thinning.
- Palm trees (blue curve) are hugely clustered, which reflects the pattern of natural regeneration, thus no farmer interventions



Applications

- These statistical analyses allow a precise description of tropical agroforests (see also Gidoin et al., 2010).
- We are interested in the impact of different spatial organisations on agronomic performances; indeed inappropriate neighbour trees or intercropping designs can lead to low yields because of nutrient and water competition as well as highly heterogeneous shade conditions, which can increase pest and disease pressure.

References

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• Ripley B. D., 1977. Modelling spatial patterns. Journal of the Royal Statistical Society, B 39, 172-212

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